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2017 International Consensus on Cardiopulmonary Resuscitation and Emergency

Cardiovascular Care Science With Treatment Recommendations Summary

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[h1]Abstract

The International Liaison Committee on Resuscitation (ILCOR) has initiated a near-continuous review of cardiopulmonary resuscitation science that replaces the previous 5-year cyclical batch-and-queue approach process. This is the first of an annual series of *International Consensus on CPR and Emergency Cardiovascular Care Science With Treatment Recommendations (CoSTR) Summary* papers that will include the cardiopulmonary resuscitation science reviewed by ILCOR in the previous year. This year's review includes 5 basic life support and 1 pediatric CoSTR. Each of these includes a summary of the science along with its quality based on Grading of Recommendations, Assessment, Development, and Evaluation criteria as well as treatment recommendations. Insights into the deliberations of the ILCOR task force members are provided in Values and Preferences sections. Finally, the task force members have prioritized and listed the top 3 knowledge gaps for each PICO (population, intervention, comparator, outcome) question.

[h1] The International Liaison Committee on Resuscitation Continuous Evidence

Review Process

Until recently, the International Liaison Committee on Resuscitation (ILCOR) cardiopulmonary resuscitation (CPR) science review process has been undertaken in 5-year cycles, the last being published in 2015.^{1,2} This batch-and-queue approach has the advantage of enabling a well-planned and systematic update of guidelines and training materials, but it could potentially delay the implementation of new effective treatments. In 2016, ILCOR adopted a new process that would enable a near-continuous review of resuscitation science by using task force–prioritized PICO (population, intervention, comparator, outcome) questions. There will be 2 distinct pathways for evidence evaluation. Knowledge synthesis units (KSUs), organizations with expertise in searching scientific databases and performing systematic reviews and meta-analyses, will address PICOs that are large and complicated or where several PICOs can be grouped and addressed through sensitivity or subgroup analyses. Contracted systematic reviewers will undertake simple systematic reviews involving typically single PICO questions. Both pathways involve content experts, and critical steps during evidence evaluation are discussed with relevant task forces whenever needed.

The Grading of Recommendations, Assessment, Development, and Evaluation (GRADE) process that was adopted for the ILCOR *2015 International Consensus on CPR and Emergency Cardiovascular Care Science With Treatment Recommendations* (CoSTR) will also be used for the continuous review of CPR science.³ In the GRADE approach, the quality of evidence supporting evidence of intervention effects (defined by the PICO question) is rated as high, moderate, low, or very low. Randomized controlled trials (RCTs) start as high-quality evidence, and observational studies start as low-quality evidence. Five factors may lead to downgrading of the quality of evidence, and 3 factors may enable an upgrade of the

quality of evidence (Table).⁴⁻⁹ The quality assessments for each outcome are summarized in GRADE evidence profile tables, which also include a summary of findings in the form of the numbers of patients, the relative risk (RR), and an indication of the absolute risk (described as the risk difference [RD]).

This is the first of a series of annual ILCOR CoSTR Summary papers that will include the CPR science reviewed by ILCOR in the previous year. This year's review includes 5 basic life support (BLS) CoSTRs and 1 pediatric CoSTR. The CoSTRs were produced after a systematic review by the KSU at St. Michael's Hospital, Toronto, Canada, in collaboration with ILCOR's content experts and members of the ILCOR BLS and Pediatric Task Forces. All the evidence profile tables and meta-analyses were produced by the KSU and reviewed by ILCOR BLS and Pediatric Task Forces. The CoSTRs have been subjected to rigorous evaluation, peer review, and public comment. We anticipate that by 2018, approximately 20 PICO questions will be addressed per year, and each one will generate a draft CoSTR that will be published on the ILCOR website (www.ilcor.org). The draft CoSTRs published online will provide the data for the annual CoSTR Summary paper that will be published in October each year. The summary paper differs in several respects from the draft CoSTRs published on the ILCOR website: the language used to describe the science is not restricted to standard GRADE terminology, which makes it more accessible to a wider audience; the values and preferences have been expanded to provide greater insight into the rationale for treatment recommendations, particularly when high-quality evidence is lacking; and the top 3 knowledge gaps for each topic have been prioritized and ranked by the task force members.

The CoSTRs are based on the data summarized in the GRADE evidence profile tables for each of the key outcomes for each of the clinical scenarios. The pertinent outcome data are

1 listed for each statement as RR (with 95% confidence interval [CI]) as well as RD (with 95%
2 CI). The RD is the absolute difference between the risks and is calculated by subtracting the
3 risk in the control group from the risk in the intervention group. This absolute effect enables a
4 more clinically useful assessment of the magnitude of the effect of an intervention and
5 enables calculation of the number needed to treat ($=1/\text{RD}$).

8 [h1] CPR Strategies: Background

9 One of the primary measures taken to improve survival after cardiac arrest has been focused
10 efforts to improve the quality of CPR. While the impact of high-quality chest compressions
11 has been studied extensively,¹⁰⁻¹³ the role of ventilation and oxygenation is less clear. Efforts
12 to simplify resuscitation by delaying ventilation or by providing passive oxygenation have
13 been implemented for both lay and professional rescuers. These strategies have been
14 consistently associated with increased bystander CPR rates and fewer pauses in chest
15 compressions, but effects on survival have been less clear.¹⁴⁻¹⁷

17 During development of the 2015 CoSTR, several PICO questions were dedicated to
18 reviewing evidence of continuous chest compression strategies for both lay and professional
19 rescuers in various populations (adult, pediatric), and for various settings (in-hospital, out-of-
20 hospital).¹⁸⁻²¹ Shortly after these reviews were completed, a 23 711-patient RCT evaluating
21 effectiveness of continuous chest compressions in the emergency medical services (EMS)
22 setting was published.²² In parallel, developments of large national and regional registries are
23 continually providing new insights into the epidemiology of cardiac arrest and bystander
24 CPR.²³ These emerging publications generated an urgent need to review all available
25 evidence on continuous compression strategies to provide updated evidence evaluations that

1 included the latest science available. The systematic review and meta-analysis of this topic
2 that was undertaken by St. Michael's Hospital KSU and ILCOR has been published
3 separately.²⁴

4 5 **[h1] The PICOST (Population, Intervention, Comparator, Outcome, Study Designs, and** 6 **Timeframe)**

7 The following PICOST was used by St. Michael's Hospital KSU when undertaking the
8 systematic review:

- 9 • Population: Patients of all ages (eg, neonates, children, adults) with cardiac arrest from
10 any cause and across all settings (in-hospital and out-of-hospital) were included. Studies
11 that included animals were not eligible.
- 12 • Intervention: All manual CPR methods, including compression-only CPR, continuous
13 compression CPR, and CPR with different compression-to-ventilation ratios, were used.
14 Compression-only CPR included compressions with no ventilations, while continuous
15 compression CPR included compressions with asynchronous ventilations or minimally
16 interrupted cardiac resuscitation. Studies that mentioned the use of a mechanical device
17 during CPR were considered only if the same device was used across all relevant
18 intervention arms and would therefore not confound the observed effect.
- 19 • Comparators: Studies had to compare at least 2 different CPR methods from the eligible
20 interventions; studies without a comparator were excluded.
- 21 • Outcomes: The primary outcome was favorable neurologic outcomes, measured by
22 cerebral performance or a modified Rankin Scale. Secondary outcomes were survival,
23 return of spontaneous circulation, and quality of life.
- 24 • Study designs: RCTs and nonrandomized studies (nonrandomized controlled trials,
25 interrupted time series, controlled before-and-after studies, cohort studies) were eligible

for inclusion. Study designs without a comparator group (eg, case series, cross-sectional studies), reviews, and pooled analyses were excluded.

- Timeframe: Published studies in English searched on January 15, 2016

[h1] Dispatch-Assisted Compression-Only CPR Compared With Dispatch-Assisted Conventional CPR (Adults): Consensus on Science

Dispatch-assisted compression-only CPR was compared with dispatch-assisted conventional CPR (ratio of 15 compressions to 2 ventilations) in one RCT that generated low-quality evidence for favorable neurologic function.¹⁵ The quality of evidence was downgraded for serious imprecision because only 2 of the 3 sites provided data on neurologic outcome. In this study, instructions to give continuous chest compressions had no demonstrable benefit for favorable neurologic function (RR, 1.25 [95% CI, 0.94 to 1.66]; RD, 2.86 percentage points [95% CI, -0.80 to 6.53]) when compared with instructions to give compressions and ventilations at a ratio of 15:2.

Dispatch-assisted compression-only CPR compared with dispatch-assisted conventional CPR (ratio of 15 compressions to 2 ventilations) in 3 RCTs provided low-quality evidence for the critical outcome of survival to hospital discharge.¹⁴⁻¹⁶ The quality of evidence for these studies was downgraded because of serious risk of bias: all 3 studies excluded patients after randomization, included an intervention that could not be blinded, and, in at least 1 study, many outcome data were missing.¹⁶ In a previously published meta-analysis of these studies, there appeared to be a small benefit in survival to hospital discharge in favor of the group instructed to give continuous chest compressions compared with the group instructed to give compressions and ventilations at a ratio of 15:2 (RR, 1.22 [95% CI, 1.01–1.46]; RD, 2.4 percentage points [95% CI, 0.1–4.9]; fixed effect model; $P=0.04$).²⁵ This meta-analysis used

survival to hospital discharge for all 3 studies,¹⁴⁻¹⁶ even though the Swenson study was missing 55% of these outcome data. In a meta-analysis using a random effect model to combine survival to hospital discharge^{14,15} and 30-day survival¹⁶ outcomes to capture the maximum amount of data, survival was no longer significantly different between the 2 groups. Continuous chest compressions had an RR for survival of 1.20 (95% CI, 1.00 to 1.45); RD, 1.88 percentage points (95% CI, -0.05 to 3.82) compared with conventional 15:2 CPR.

[h2] Treatment Recommendation

We recommend that dispatchers provide chest compression–only CPR instructions to callers for adults with suspected out-of-hospital cardiac arrest (OHCA) (strong recommendation, low-quality evidence).

[h2] Values and Preferences

In making these recommendations, we recognize that the evidence in support of these recommendations comes from randomized trials of variable quality, performed at a time when the ratio of chest compressions to ventilations was 15:2, which leads to greater interruptions to chest compressions than the currently recommended ratio of 30:2. However, the signal from every trial is consistently in favor of telephone CPR protocols that use a compression-only CPR instruction set. Reviewing the totality of available evidence and considering current common practice, training, and quality assurance experiences, the BLS Task Force has kept the strong recommendation for compression-only CPR for dispatch-assisted CPR despite low-quality evidence. In making these recommendations, we placed a higher value on the initiation of bystander compressions and a lower value on possible harms of delayed ventilation. The task force recognizes that there are many unanswered questions

when balancing possible benefits and harms from bystander ventilation. Most notably, while some cardiac arrest etiologies (eg, asphyxial cardiac arrest) might be dependent on early ventilation to increase survival, bystanders' ability to learn how to perform mouth-to-mouth ventilations over the phone is not known. Possible harmful effects of incorrectly performed ventilations (gastric inflation) and fewer compressions performed before ambulance arrival because of more complex instructions and pauses for ventilation were weighted more heavily than potential benefits from early ventilation.

This document refers to *dispatch-assisted CPR*. In adopting this terminology, we acknowledge that the dispatching of emergency medical resources is a limited description of the tasks performed by multiprofessional teams working in emergency medical dispatch centers, and perhaps more suitable options are being used worldwide. Those include telecommunicators, ambulance communication officers, emergency medical communicators, and call handlers, as well as other terms more closely related to their actual task description.

[h2] Knowledge Gaps

Several knowledge gaps were identified while reviewing this topic. A more comprehensive list has been posted on the ILCOR website (www.ilcor.org). The BLS Task Force ranked the knowledge gaps in priority order, and the top 3 are

1. What is the optimal instruction sequence for coaching callers in dispatch-assisted CPR?
2. What are the identifying key words used by callers that are associated with cardiac arrest?
3. What is the impact of dispatch-assisted CPR instructions on noncardiac etiology arrests such as drowning, trauma, or asphyxia in adult and pediatric patients?

[h1] Bystander Compression-Only CPR Compared With Bystander CPR Using Compressions and Ventilations (Adults): Consensus on Science

Bystander CPR using chest compressions only was compared with bystander CPR using a compression-to-ventilation (CV) ratio of 15:2 or 30:2 in 6 cohort studies that generated very-low-quality evidence for the critical outcome of favorable neurologic function.^{23,26-30} In a meta-analysis of 2 studies, there was no significant difference in favorable neurologic function in patients who received compression-only CPR compared with patients who received CPR at a CV ratio of 15:2 (RR, 1.34 [95% CI, 0.82 to 2.20]; RD, 0.51 percentage points [95% CI, -2.16 to 3.18]).^{26,28} The quality of evidence was downgraded for serious indirectness and imprecision because of varying results across studies, the control group had a different CV ratio from the intervention group, and there was variable postarrest care. In a meta-analysis of 3 studies, there was no significant difference in favorable neurologic function in patients who received compression-only CPR compared with patients who received compressions and ventilations during a period when the CV ratio changed from 15:2 to 30:2 (RR, 1.12 [95% CI, 0.71 to 1.77]; RD, 0.28 percentage points [95% CI, -2.33 to 2.89]).^{27,29,30} The quality of evidence was downgraded for serious indirectness and imprecision because the control group had a different CV ratio from the intervention group and there was variable postarrest care. One study examined the influence of nationwide dissemination of compression-only CPR recommendations for lay rescuers and showed that although bystander CPR rates and nationwide survival improved, patients who received compression-only CPR had lower survival compared with patients who received chest compressions and ventilations at a CV ratio of 30:2 (RR, 0.72 [95% CI, 0.69 to 0.76]; RD, -0.74 percentage points [95% CI, -0.85 to 0.63]).²³ The quality of evidence was downgraded for serious indirectness because the study did not directly compare compression-only CPR to

CPR with chest compressions and ventilations but rather compared compression-only and CPR with chest compressions and ventilations to no CPR. The evidence was also considered indirect because multiple aspects of resuscitation were likely to have changed over time in this before-and-after study.

Bystander CPR using compression-only CPR was compared with bystander CPR using a CV ratio of 15:2 or 30:2 in 7 cohort studies that generated very-low-quality evidence for the critical outcome of survival.^{23,26,28,31-34} In a meta-analysis of 6 studies, there was no significant difference in survival in patients who received compression-only CPR compared with patients who received CPR at a CV ratio of 15:2 (RR, 0.88 [95% CI, 0.74 to 1.04]; RD, -0.83 percentage points [95% CI, -1.85 to 0.19]).^{26,28,31-34} The quality of evidence was downgraded for serious risk of bias and indirectness. Risk of bias was related to the comparability of the cohorts because the majority did not adjust for potential confounders. The studies were also downgraded for indirectness because they were either investigating CPR guideline changes or did not explicitly report the CV ratio among included cases. In one study, patients receiving compression-only CPR had worse survival compared with patients who received CPR at a CV ratio of 30:2 (RR, 0.75 [95% CI, 0.73 to 0.78]; RD, -1.42 percentage points [95% CI, -1.58 to -1.25]).²³ The quality of evidence was downgraded for serious indirectness as described above. In a meta-analysis of 3 observational studies,^{27,29,30} there was no significant difference in survival when patients who received compression-only CPR were compared with patients who received CPR during a period when the CV ratio changed from 15:2 to 30:2 (RR, 1.16 [95% CI, 0.64 to 2.09]; RD, 1.27 percentage points [95% CI, -3.70 to 6.23]). The quality of evidence was downgraded for serious inconsistency, indirectness, and imprecision as described above.

[h2] Treatment Recommendations

We continue to recommend that bystanders perform chest compressions for all patients in cardiac arrest (good practice statement). In the 2015 CoSTR, this was cited as a strong recommendation but based on very-low-quality evidence.^{18,19}

We suggest that bystanders who are trained, able, and willing to give rescue breaths as well as chest compressions do so for all adult patients in cardiac arrest (weak recommendation, very-low-quality evidence).

[h2] Values and Preferences

In making these recommendations, the task force placed high value on the 2010 and 2015 CoSTRs that showed rescuers should perform chest compressions for all patients in cardiac arrest.^{18,19,35,36} Given that the 2017 systematic review did not seek data comparing any CPR with no CPR, and in keeping with GRADE recommendations, our recommendation for performing chest compressions for all patients in cardiac arrest has been cited as a *good practice statement* (see Glossary).³⁷ We also placed high value on the advantage derived from the simplicity of teaching or providing instructions for compression-only CPR. This recommendation reflects the value placed on the data that indicate no apparent downside in true arrest patients with similar survival rates from adult cardiac arrests of cardiac etiology both with and without ventilations.^{38,39} We also acknowledged the potential additional benefits of CPR with compressions and ventilations when delivered by trained laypersons, particularly in settings where EMS response intervals are long or when the cause of cardiac arrest is asphyxia.

[h2] Knowledge Gaps

Several knowledge gaps were identified while reviewing this topic. A more comprehensive list has been posted on the ILCOR website (www.ilcor.org). The BLS Task Force ranked the knowledge gaps in priority order, and the top 3 are

1. The effect of delayed ventilation versus 30:2 high-quality CPR
2. The impact of continuous chest compressions on outcomes for noncardiac etiology arrests such as drowning, trauma, or asphyxia in adult and pediatric patients
3. The ability of bystanders to perform correct mouth-to-mouth ventilations

[h1] EMS-Delivered CPR: Consensus on Science

High-quality CPR includes minimal interruptions to chest compressions. There are 3 distinct techniques used by EMS to deliver continuous chest compression CPR during OHCA: (a) continuous chest compressions with positive-pressure ventilation (PPV) of the lungs using a bag-mask device typically at a rate of 10/min; (b) continuous chest compressions and PPV of the lungs via a tracheal tube or supraglottic airway; and (c) continuous chest compressions with passive oxygenation using typically an oropharyngeal airway and simple oxygen mask (a strategy sometimes referred to as *minimally interrupted cardiac resuscitation*). Studies involving these techniques have typically delayed insertion of an advanced airway until after return of spontaneous circulation or 3 cycles of CPR.

For the critical outcome of favorable neurologic function, we identified high-quality evidence from 1 RCT²² and very-low-quality evidence from 2 cohort studies.^{17,40} In the RCT, patients who were randomized to PPV delivered with a bag-mask device without pausing chest compressions had no demonstrable benefit for favorable neurologic function (RR, 0.92 [95% CI, 0.84 to 1.00]; RD, -0.65 percentage points [95% CI, -1.31 to 0.02]) when compared with patients randomized to conventional CPR with a CV ratio of 30:2.²² In one cohort study,

patients who received continuous chest compressions and passive ventilation for 3 cycles had improved favorable neurologic function (RR, 2.58 [95% CI, 1.5–4.47] RD, 24.11 percentage points [95% CI, 11.58–36.63]) compared with those who received compressions and ventilations at a time when the CV ratio changed from 15:2 to 30:2.⁴⁰ The quality of evidence was downgraded for serious risk of bias and indirectness. Risk of bias included moderate risk that the continuous chest compression cohort was not representative and high risk that there were confounding factors between the cohorts that were not adjusted for. The study was considered indirect because of its before-and-after design including a period with changing guidelines. In the other cohort study,¹⁷ patients with witnessed shockable cardiac arrest who received minimally interrupted cardiac resuscitation (initial series of 3 cycles of 200 uninterrupted chest compressions; passive ventilation; before-and-after rhythm analysis with shock, if appropriate) had no demonstrable benefit for favorable neurologic function (RR, 0.81 [95% CI, 0.57 to 1.13]; RD, –11.30 percentage points [95% CI, –28.48 to 5.87]) when compared with conventional CPR (mixture of CV ratios of 15:2 and 30:2). The quality of evidence was downgraded for serious risk of bias, indirectness, and imprecision. Risk of bias included moderate risk that the continuous chest compression cohort was not representative and unclear risk of inadequate follow-up. The study was considered indirect because of its before-and-after design including a period with changing guidelines and imprecise because the CIs for RD crossed from appreciable harm (0.75) to appreciable benefit (1.25).

For the critical outcome of survival, we identified high-quality evidence from 1 RCT²² and very-low-quality evidence from 1 cohort study.¹⁷ In the RCT, there was no significant difference in survival to discharge of patients randomized to continuous chest compressions compared with patients randomized to conventional CPR with a CV ratio of 30:2 (RR, 0.92 [95% CI, 0.85 to 1.00]; RD, –0.76 percentage points [95% CI, –1.51 to 0.02]).²² In the cohort

study,¹⁷ patients with witnessed shockable cardiac arrest who received minimally interrupted cardiac resuscitation had improved survival (RR, 2.37 [95% CI, 1.69–3.31]; RD, 5.24 percentage points [95% CI, 2.88–7.60]) compared with conventional CPR using a mixture of 30:2 and 15:2 CV ratios. The quality of evidence was downgraded for serious indirectness and imprecision as described above.

[h2] Treatment Recommendations

We recommend EMS providers perform CPR with 30 compressions to 2 ventilations or continuous chest compressions with PPV delivered without pausing chest compressions until a tracheal tube or supraglottic device has been placed (strong recommendation, high-quality evidence).

We suggest that where EMS systems have adopted minimally interrupted cardiac resuscitation, this strategy is a reasonable alternative to conventional CPR for witnessed shockable OHCA (weak recommendation, very-low-quality evidence).

[h2] Values and Preferences

In making these recommendations, the task force took into consideration that although there was relative homogeneity in the body of evidence around EMS continuous chest compressions and adjunctive therapies (eg, bundles of care in the community, such as improved bystander CPR strategies, and hospital systems of care, such as transfers to resuscitation centers), there was heterogeneity in the continuous CPR ventilation strategies (ie, passive versus PPV strategies) and in the comparator groups. The recommendations reflect high-quality evidence about the safety of CPR with compressions and ventilations (CV ratio 30:2) by EMS providers while acknowledging the lack of data supporting superior

functional or survival outcomes. The task force also placed a relatively high value on the importance of providing high-quality chest compressions and simplifying resuscitation logistics for EMS systems and noted the support for the clinical benefit of bundles of care involving minimally interrupted cardiac resuscitation. In making a weak recommendation in support of systems that have implemented minimally interrupted cardiac resuscitation, the task force also acknowledges the lack of RCTs evaluating passive oxygenation strategies such as those described in minimally interrupted cardiac resuscitation.

[h2] Knowledge Gaps

Several knowledge gaps were identified while reviewing this topic. A more comprehensive list has been posted on the ILCOR website (www.ilcor.org). The BLS Task Force ranked the knowledge gaps in priority order, and the top 3 are

1. What is the effect of delayed ventilation versus 30:2 high-quality CPR?
2. Which elements of the bundled care (compressions, ventilations, delayed defibrillation) are most important?
3. How effective is passive oxygen insufflation (applying a flow of oxygen via a face mask or a supraglottic airway but without PPV)?

[h1] In-Hospital CPR: Consensus on Science

Only 1 cohort study evaluating the effect of continuous chest compressions was identified for the in-hospital setting.⁴¹ In this study, PPV without interruption of chest compressions after tracheal intubation was compared with interruption of chest compressions for 1 ventilation after every fifth chest compression (a CV ratio of 5:1) among patients admitted to a hospital emergency department after OHCA. Chest compressions were delivered by a mechanical device known as the *Thumper* in all patients, a device that is not commonly used clinically

and that delivered different average compression rates (70/min vs 100/min) between the study periods. The study compared continuous chest compressions and ventilations delivered after every tenth compression (without pausing compressions) with a 5:1 CV ratio (with pauses for ventilation) that resulted in more frequent pauses in compressions and higher overall ventilation rates than the conventional 30:2 CV ratio recommended by the 2015 CoSTR.^{18,19} It was conducted using a before-and-after design that, while adjusted for demographic and cardiac arrest characteristics, did not account for potential temporal differences in resuscitation efficiencies between the study periods.

Very-low-quality evidence was identified for the critical outcome of favorable neurologic function.⁴¹ There was no difference in favorable neurologic outcome between uninterrupted 10:1 CPR and interrupted 5:1 CPR cohorts (RR, 1.18 [95% CI, 0.32 to 4.35]; RD, 0.29 percentage points [95% CI, -2.05 to 2.64]). The quality of evidence was downgraded to very serious imprecision as CIs for RD crossed from appreciable harm (0.75) to appreciable benefit (1.25).

Low-quality evidence was identified for the critical outcome of survival.⁴¹ The uninterrupted 10:1 CPR cohort had a higher survival rate to hospital discharge compared with the interrupted 5:1 CPR cohort (RR, 2.38 [95% CI, 1.22–4.65]; RD, 5.86 percentage points [95% CI, 1.19–10.53]).

[h2] Treatment Recommendation

Whenever tracheal intubation or a supraglottic airway is achieved during in-hospital CPR, we suggest providers perform continuous compressions with PPV delivered without pausing chest compressions (weak recommendation, very-low-quality evidence).

1

2 [h2] Values and Preferences

3 In making this recommendation, the task force noted that there is no prospective study of in-
 4 hospital CPR that compares delivery of ventilations during continuous manual chest
 5 compressions with ventilations delivered during pauses in manual chest compressions. The
 6 task force placed value in that delivering continuous chest compressions is a common
 7 practice in many settings after tracheal intubation or placement of a supraglottic airway. The
 8 only study to have addressed this specific question in an in-hospital setting has limited
 9 applicability in that it was performed after OHCA and in context of mechanical chest
 10 compressions along with other limitations. However, the findings of this support the
 11 treatment recommendation.

12

13 [h2] Knowledge Gaps

14 Several knowledge gaps were identified while reviewing this topic. A more comprehensive
 15 list has been posted on the ILCOR website (www.ilcor.org). The BLS Task Force ranked the
 16 knowledge gaps in priority order, and the top 3 are

- 17 1. There is no prospective study of in-hospital CPR that compares delivery of
 18 ventilations during continuous manual chest compressions with ventilations delivered
 19 during pauses in manual chest compressions
- 20 2. The effect of delayed ventilation versus 30:2 high-quality CPR
- 21 3. What is the optimal method for ensuring a patent airway?

22

23 [h1] Chest Compression-to-Ventilation Ratio (Adults): Consensus on Science

24 The 30:2 CV ratio was compared with a different CV ratio in 2 observational cohort studies
 25 that generated very-low-quality evidence for the critical outcome of favorable neurologic

function.^{42,43} In a meta-analysis of these studies, the 30:2 CV ratio demonstrated benefit for favorable neurologic function (RR, 1.34 [95% CI, 1.02–1.76]; RD, 1.72 percentage points [95% CI, 0.52–2.91]), compared with the CV ratio of 15:2. The quality of evidence was downgraded for serious indirectness because these studies were before-and-after investigations that evaluated the bundle-of-care interventions implemented after the 2005 *American Heart Association Guidelines for CPR and Emergency Cardiovascular Care*,^{44,45} in which the change in CV ratio was just 1 aspect.

Seven observational cohort studies provided very-low-quality evidence for the critical outcome of survival.^{42,43,46-50} The quality of evidence was downgraded for serious indirectness because the CV ratio was not the only aspect evaluated in these studies. In a meta-analysis of 6 cohort studies, the survival rate was higher in the group of patients who received 30:2 CPR compared with the group who received 15:2 CPR (RR, 1.37 [95% CI, 1.19–1.59]; RD, 2.48 percentage points [95% CI, 1.57–3.38]).^{42,43,46,48-50} One retrospective cohort showed improved survival with the 50:2 CV ratio compared with the 15:2 ratio (RR, 1.96 [95% CI, 1.28–2.99]; RD, 21.48 percentage points [95% CI, 6.90–36.06]).⁴⁷ The quality of evidence was downgraded for serious risk of bias and indirectness. Risk of bias included high risk that the cohorts were not comparable on basis of design or analysis and moderate risk of inadequate follow-up. The study was also considered indirect because of its before-and-after design potentially evaluating several changes to practice.

[h2] Treatment Recommendation

We suggest a CV ratio of 30:2 compared with any other CV ratio in patients with cardiac arrest (weak recommendation, very-low-quality evidence).

[h2] Values and Preferences

In making this recommendation, the task force acknowledged that there would likely be substantial resource implications (eg, reprogramming, retraining) associated with a change in recommendation related to the CV ratio. In the absence of any data addressing the critical outcomes, the task force placed a high value on maintaining consistency with the 2005, 2010, and 2015 CoSTR.^{18,19,35,36,44,45} We also placed high value on findings that suggest that a bundle of care (which included a CV ratio of 30:2) resulted in more lives being saved.

[h2] Knowledge Gaps

Several knowledge gaps were identified while reviewing this topic. A more comprehensive list has been posted on the ILCOR website (www.ilcor.org). The BLS Task Force ranked the knowledge gaps in priority order, and the top 3 are

1. Possible benefit of higher CV ratios (more compressions per ventilations)
2. The ability of CPR providers to deliver 2 effective ventilations during the short pause in chest compressions during CPR
3. Is there a ratio-dependent critical volume of air movement required to maintain effectiveness?

[h1] Bystander CPR for Pediatric OHCA: Consensus on Science

A recent systematic review compared outcomes associated with bystander compression-only CPR with those of bystander CPR that included chest compressions plus ventilation for pediatric OHCA.²⁴ The review identified 2 large observational cohort studies, both using data from Japan's nationwide All-Japan Utstein OHCA registry.^{51,52} This large mandatory registry includes all cardiac arrests of all ages in Japan, and includes both cardiac and noncardiac (eg, trauma, hanging, drowning, drug overdose, asphyxia respiratory diseases, cerebrovascular

diseases, malignant tumors) etiologies. As of 2017, it contains data from more than 1 million cardiac arrests.

The Kitamura et al study includes 5170 events in children 17 years and younger, including 2439 events where bystander CPR was performed, captured from 2005 through 2007.⁵¹ At the time of the study, resuscitation guidelines in Japan were transitioning from a CV ratio of 15:2 to 30:2 for pediatric OHCA. The Goto et al study includes 5056 events in children younger than 18 years of age, including 2722 events where bystander CPR was performed, captured from 2008 through 2010.⁵² At the time of the study, pediatric CPR guidelines in Japan recommended CPR that included ventilation with a CV ratio of 30:2. In addition, national implementation of a dispatch-assisted CPR program was occurring.

The quality of evidence was downgraded to very low for the critical outcome of favorable neurologic function (Pediatric Cerebral Performance Category [PCPC] 1 or 2) at 1 month.^{51,52} The quality of evidence for these studies was downgraded because of serious risk of bias (eg, potential variability between comparison groups, single-country/healthcare system registry, variability in protocols among fire/EMS departments), serious indirectness (ie, the CV ratio provided was not specifically described in the publications and had to be deduced from the description of the guidelines and recommendations that were reported to be used at the time of data collection), and serious imprecision (wide CIs). In the first study, in all children, survival with favorable neurologic function (PCPC 1 or 2) was less likely among children receiving chest compression-only CPR (RR, 0.46 [95% CI, 0.29–0.73]; RD, 3.02 percentage points [95% CI, 1.47–4.57]).⁵¹ After further subgroup analysis by age, patients 1 to 17 years with bystander chest compression-only CPR had worse outcomes (RR, 0.46 [95% CI, 0.28–0.75]; RD, 4.34 percentage points [95% CI, 1.95–6.73]). In infants, outcome was uniformly

poor, and there was no demonstrable difference in favorable neurologic function whether bystanders provided chest compression–only CPR or CPR with ventilation (RR, 0.39 [95% CI, 0.11 to 1.36]; RD, 1.31 percentage points [95% CI, –0.17 to 2.80]). The second study did not report results divided by age subgroups but identified fewer patients overall with favorable neurologic function (PCPC 1 or 2) in the chest compression–only CPR group than in those receiving CPR with a CV ratio of 30:2, (RR, 0.45 [95% CI, 0.31–0.66]; RD, 3.30 percentage points [95% CI, 1.71–4.88]).⁵² These data were not published in the original manuscript but were provided via email from the corresponding author of the study (Yoshikazu Goto, MD, PhD, personal email communication, unpublished data, May 2, 2014).

The quality of evidence was very low for the critical outcome of survival to 1 month.^{51,52} The quality of evidence for these studies was downgraded because of serious risk of bias, serious indirectness, and serious imprecision (see reasons for downgrading above). In the Kitamura et al study, outcomes were worse for all children who received bystander chest compression–only CPR when compared with those who received CPR with ventilation (RR, 0.76 [95% CI, 0.60–0.97]; RD, 2.98 percentage points [95% CI, 0.45–5.51]).⁵¹ After further subgroup analysis by age, patients aged 1 to 17 years who received chest compression–only CPR had worse outcomes (RR, 0.70 [95% CI, 0.53–0.93]; RD, 4.74 percentage points [95% CI, 1.17–8.31]). In infants, there was no demonstrable difference in survival to 1 month (RR, 0.90 [95% CI, 0.56 to 1.45]; RD, 0.74 percentage points [95% CI, –2.61 to 4.09]). In the Goto et al study, survival was worse among children who received chest compression–only CPR compared with those who received CPR with ventilation (RR, 0.56 [95% CI, 0.45–0.69]; RD, 7.04 percentage points [95% CI, 4.50–9.58]).⁵² There was no subgroup analysis for different ages in this study.

[h2] Treatment Recommendations

We suggest that bystanders provide CPR with ventilation for infants and children younger than 18 years with OHCA (weak recommendation, very-low-quality evidence).

We continue to recommend that if bystanders cannot provide rescue breaths as part of CPR for infants and children younger than 18 years with OHCA, they should at least provide chest compressions (good practice statement). In the 2015 CoSTR, this was cited as a strong recommendation but based on very-low-quality evidence.^{20,21}

[h2] Additional Science Published Since the Systematic Review Was Completed

After the systematic review was completed, 2 additional relevant observational studies were published,^{53,54} and they have informed the task force decision in their treatment recommendation.

Very-low-quality evidence was identified for the critical outcome of favorable neurologic function (PCPC 1 or 2) at hospital discharge.⁵³ The GRADE quality for this study was downgraded for serious risk of bias (observational study with possible variability between comparison groups) and serious indirectness (specific CPR CV ratio not listed) from one cohort study. This study is from a voluntary American OHCA registry of nontraumatic cardiac arrest that represents a catchment area of more than 90 million people in 37 states.

This study included 3900 events captured from 2013 through 2015 and compared the outcomes of children receiving either bystander chest compression–only CPR or bystander CPR with ventilation for the 1411 children for whom data were available about the type of CPR provided. Data from eFigure4 of this study indicate that there was no difference in favorable neurologic function when comparing infants who received chest compression–only

CPR with those who received CPR with ventilation ($P=0.083$), as well as no difference among children (1 through 17 years of age) who received chest compression–only CPR when compared with those who received CPR with ventilation ($P=0.117$).⁵³

Very-low-quality evidence has been identified for the critical outcome of favorable neurologic function (PCPC 1 or 2) at 1 month.⁵⁴ This study was another observational study from the all-Japan registry. The level of evidence for this study was downgraded for serious risk of bias (observational study with possible variability between comparison groups), serious indirectness (specific CPR CV ratio not listed), and very serious imprecision (very wide CI). This Japanese OHCA registry study (including traumatic cardiac arrest) reported 2157 events in children older than 1 year (ie, no infants) and younger than 18 years, captured from 2011 through 2012, and compared the outcomes of children receiving either bystander chest compression–only CPR or bystander CPR with ventilation for the 1150 children for whom data were available about the type of CPR provided. The study was performed at a time when Japan CPR guidelines recommended a CV ratio of 30:2, and an established national dispatch-assisted CPR protocol existed. Favorable neurologic function was no different among children who received chest compression–only CPR or CPR with ventilation (adjusted odds ratio [aOR], 1.52 [95% CI, 0.93–2.49]).

Very-low-quality evidence has been identified for the critical outcome of survival to 1 month.⁵⁴ The quality of evidence for this cohort study was downgraded for serious risk of bias, serious indirectness, and very serious imprecision (see explanations above). In this study, 1-month survival in children (1 to 18 years) was no different whether they received chest compression–only CPR or CPR with ventilation (aOR, 1.38 [95% CI, 0.98–1.96]).

Very-low-quality evidence has been identified for the critical outcome of survival to hospital discharge.⁵³ The quality of evidence for this cohort study was downgraded for serious risk of bias (see above). In infants with OHCA, survival to hospital discharge was worse in those receiving chest compression–only CPR when compared with those receiving CPR with ventilation ($P=0.002$). Conversely, for children 1 year or older, there was no difference in survival to hospital discharge when comparing those who received bystander chest compression–only CPR with those who received CPR with ventilation ($P=0.258$).

[h2] Values and Preferences

Bystander CPR improves survival, and CPR treatment recommendations should strive to enhance ease of CPR implementation and CPR effectiveness. Most pediatric cardiac arrests are asphyxial in etiology, so effective CPR is likely to require ventilation in addition to chest compressions. In making these recommendations, the task force placed a higher value on the importance of rescue breaths as part of pediatric CPR over a strategy that deemphasizes ventilation to simplify CPR instructions and skills. The 2 (observational) papers published since the completion of the systematic review suggest that survival and neurologic outcome may not differ among children (ie, 1 year or older) who receive bystander compression-only CPR or CPR with ventilation.^{53,54} This conclusion differs from previous evidence that suggested the superiority of CPR with ventilation for all ages of pediatric victims of OHCA.^{20,55} Available data are now inconsistent and somewhat contradictory when comparing bystander compression-only CPR to CPR with ventilation for infant (younger than 1 year) OHCA. These discrepancies in findings, especially those coming from the more recent publications, helped inform task force decisions with respect to the bystander CPR with ventilation versus compression-only CPR treatment recommendations and explain the rationale behind the task force’s decision to downgrade the strength of the treatment

recommendation to the weaker terminology of *suggests* instead of the stronger term *recommends*. This relative clinical equipoise should stimulate the development of prospective clinical trials to definitively determine the optimal bystander CPR technique for infants (younger than 1 year) and children (1 year or older).

Despite the availability of only very-low-quality evidence (analyzed as part of the 2015 ILCOR evidence evaluation process), the task force unanimously agreed to reiterate the 2015 strong treatment recommendation for providing “any CPR” (including compression-only CPR) over “no CPR” for pediatric OHCA, because the potential benefit outweighs any potential harm. Given that the systematic review did not seek data comparing “any CPR” with “no CPR” and in keeping with GRADE recommendations, our recommendation has been cited as a *good practice statement* (see Glossary).³⁷

[h2] Knowledge Gaps

In order of priority, the top knowledge gaps for this topic are

1. More high-quality studies are needed to compare compression-only CPR to CPR with ventilation for infants and children with out-of-hospital cardiac arrest.
2. Data are needed from other resuscitation registries that will enable comparison of the role of ventilation with CPR because, based largely on differences in local resuscitation council guidelines, this varies worldwide. This should also include subgroup analysis of different patient ages (eg, infancy, 1–8 years, older than 8 years) and etiologies of cardiac arrest.
3. Can telephone dispatchers coach bystanders to provide effective rescue breaths/CPR with ventilation for infants and children?

[h1] Glossary of Terms Used in This Paper

Advanced airway	Tracheal tube or supraglottic airway
Compression-only CPR	Chest compressions without active ventilation (eg, mouth-to-mouth, bag-mask ventilation, or ventilation via an advanced airway)
CPR with ventilation	Chest compressions with positive-pressure ventilation; this includes a variety of chest compression-to-ventilation ratios and continuous chest compressions with ventilations delivered without pausing chest compressions.
Continuous chest compression CPR	Chest compressions delivered without pausing for ventilation. Positive-pressure ventilations may (often at 10 breaths per minute) or may not be provided. Maintenance of airway patency may enable passive ventilation.
Dispatch-assisted CPR	A bystander provides CPR under telephone instruction by an EMS dispatcher—this is most often compression-only CPR. Alternative terminology for these dispatchers includes <i>telecommunicators</i> , <i>ambulance communication officers</i> , <i>emergency medical communicators</i> , and <i>call handlers</i> .

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[h1] GRADE Terminology

Risk of bias	Study limitations in randomized trials include lack of allocation concealment, lack of blinding, incomplete accounting of patients and outcome events, selective outcome reporting bias, and stopping early for benefit. Study limitations in observational studies include failure to apply appropriate eligibility criteria, flawed measurement of exposure and outcome, failure to adequately control confounding, and incomplete follow-up.
Inconsistency	Criteria for inconsistency in results include the following: point estimates vary widely across studies, confidence intervals show minimal or no overlap, statistical test for heterogeneity shows a low <i>P</i> value, and the I^2 is large (a measure of variation in point estimates due to among-study differences).
Indirectness	Sources of indirectness include differences in population (eg, out-of-hospital cardiac arrest instead of in-hospital cardiac arrest, adults instead of children); differences in the intervention (eg, different compression-to-ventilation ratios); differences in outcome; and indirect comparison.

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Imprecision

Low event rates and/or small sample sizes will generally result in wide confidence intervals and, therefore, imprecision.

Publication bias

Several sources of publication bias include tendency not to publish negative studies and influence of industry-sponsored studies. An asymmetrical funnel plot increases suspicion of publication bias.

Good practice statements

Guideline panels often consider it necessary to issue guidance on specific topics that don't lend themselves to a formal review of research evidence. This might be because research into the topic is unlikely to be located and/or would be considered unethical or nonfeasible. Criteria for issuing a nongraded good practice statement include overwhelming certainty that the benefits of the recommended guidance will outweigh harms and a specific rationale is provided, the statements should be clear and actionable to a specific target population, the guidance is deemed necessary and might be overlooked by some providers if not specifically communicated, and the recommendations should be readily implementable by the specific target audience the guidance is directed toward.

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1 **Table. GRADE Quality Assessment Criteria**

Study Design	Quality of Evidence	Lower if	Higher if
Randomized trial	High	<ul style="list-style-type: none"> • Risk of bias 	<ul style="list-style-type: none"> • Large effect
	Moderate	<ul style="list-style-type: none"> • Inconsistency 	<ul style="list-style-type: none"> • Dose response
Observational study	Low	<ul style="list-style-type: none"> • Indirectness 	<ul style="list-style-type: none"> • All plausible confounding: would reduce a demonstrated effect or would suggest a spurious effect when results show no effect
	Very low	<ul style="list-style-type: none"> • Imprecision • Publication bias 	

2 Adapted from Guyatt et al.³

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